TOTAL IONIZING DOSE TEST REPORT

BFR92A NPN 5 GHz Wide Band Transistor from NXP

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1. Purpose

The purpose of this test was to characterize the Philips/NXP BFR92A NPN 5GHz wide band silicon transistor for total dose response. This test shall serves as the radiation lot acceptance test (RLAT) for the lot date code (LDC) 1027. The BFR92A is packaged in a 3-pin plastic SOT23 package. Low dose rate (LDR/ELDRS) irradiations was performed.

2. Test Samples

Eleven (11) parts from the flight lot of BFR92As were being provided to Code 561 for total ionizing dose (TID) testing. One of the eleven shall be used as a control. More information can be found in Table 1. A photograph of the packaged part mounted on an adapter board is shown in Figure 1. The pin assignments for the BFR92A in the SOT23 package are shown in Figure 2. Figure 3 shows the adapter boards mounted in sockets on the bias board used in TID exposures.

Generic Part Number:	BFR92A
Full Part Number	BFR92A-215
Manufacturer:	NXP
Lot Date Code (LDC):	1027
Quantity Tested:	10, plus control
Serial Numbers of Control Sample:	0
Serial Numbers of Radiation Samples:	1-5 Biased 6-10 Unbiased
Part Function:	NPN high frequency transistor
Part Technology:	Bipolar
Case Markings:	P2W07
Package Style:	SOT23
Test Equipment:	Keithley S4200 parameter analyzer, Keithley CV meter, Tektronix 7703B digital oscilloscope, RF generator, Keithley meters
Test Engineer:	Anthony Phan
Dose Levels (krad (Si)):	2, 5, 10, 15, and 20 krads (Si)
Target dose rate (rad (Si)/min):	0.01 rad/sec

Table 1. Part and test information.

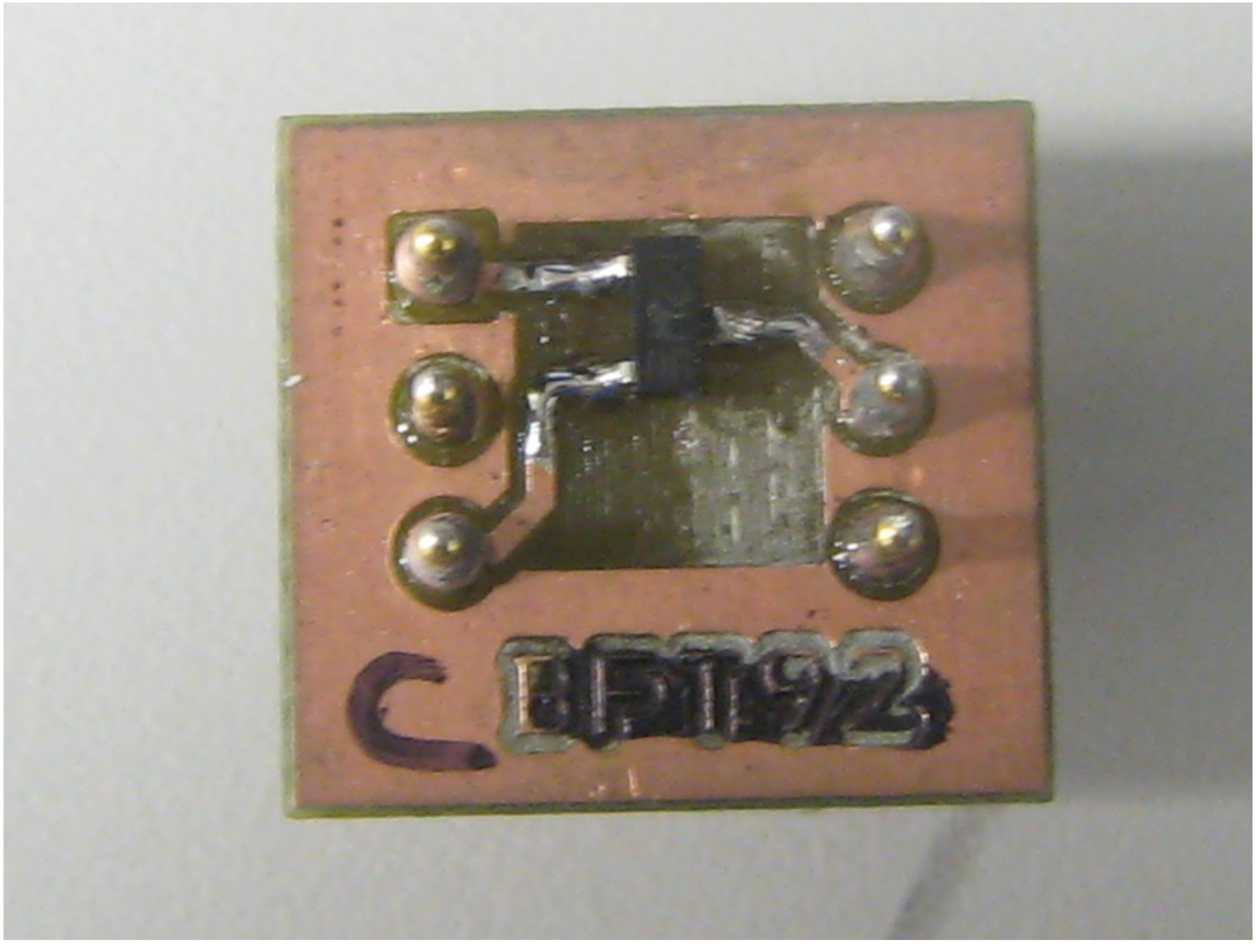

Figure 1. Photograph of the BFR92A mounted on an adapter board, which in turn was inserted into a test socket.

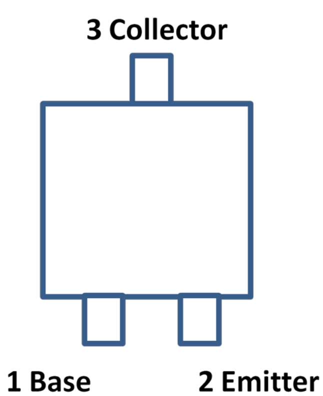

Figure 2. Pin assignments for the BFT92A in the SOT23 package are shown.

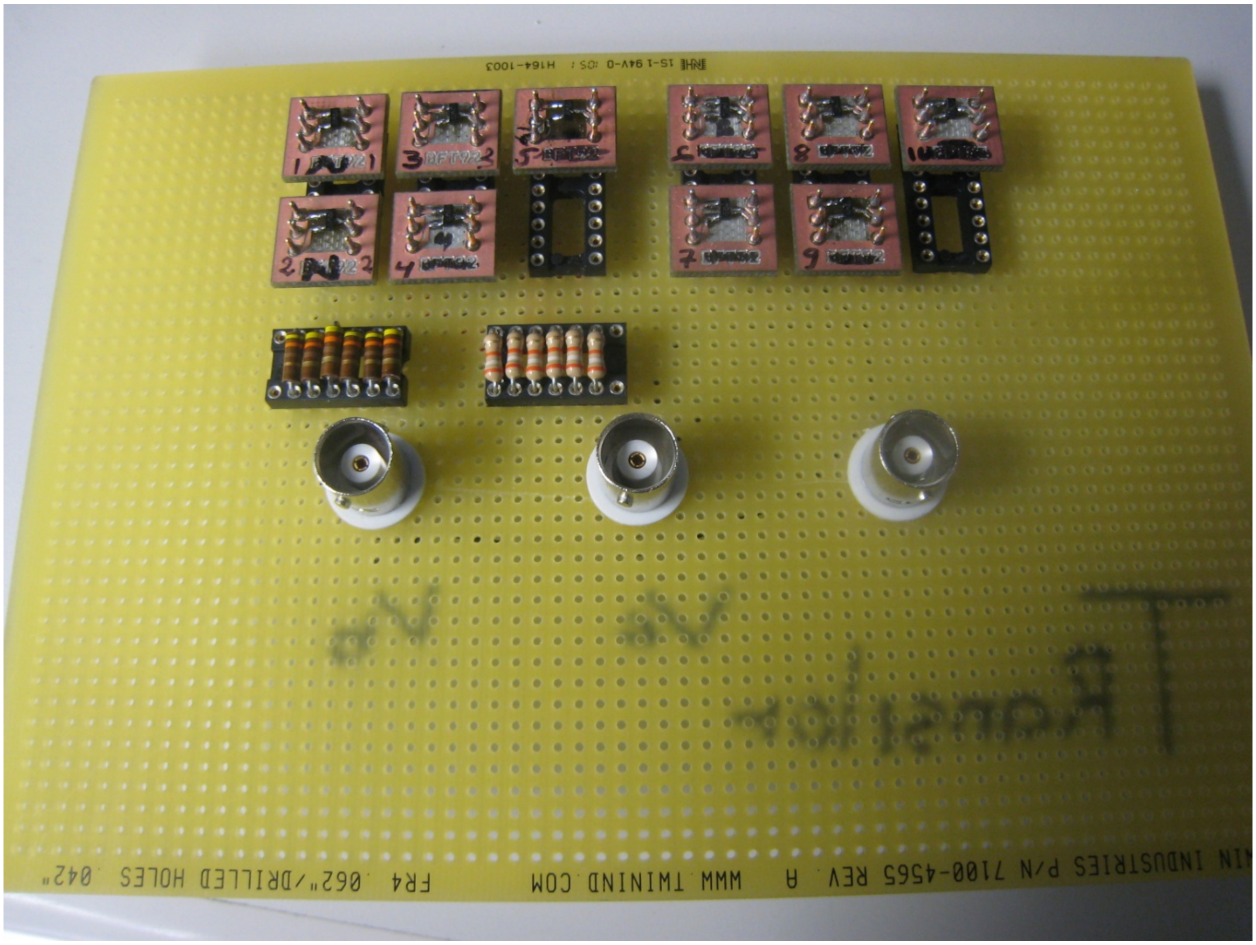

Figure 3. Bias board used in TID exposures, with ten DUTs mounted on adapter boards, mounted in sockets.

3. General

Radiation testing was done by exposing the BFR92A samples to gamma radiation at dose rate approximately equal to 0.01 rad(Si)/s (TM 1019 Condition D). Eleven parts were tested – ten exposed to radiation and the eleventh as a control. Five parts were tested without bias, with all pins grounded. The other five parts were biased as shown in Fig. 4. Prior to the first radiation dose, all ten parts were electrically tested using a parametric analyzer. After each exposure level, the parts were tested again. Parts were subjected to multiple levels of total dose and step level tested as shown in Table 2. The total dose source was the GSFC ^{60}Co irradiator in the Radiation Effects Facility, which is compliant with MIL-STD-883, Method 1019. Dosimetry is NIST traceable. Testing and post-irradiation annealing were done at room temperature, approximately 25°C.

Table 1: Device Grouping and Step-Stress Instructions

S/N	Qty	Bias	Sample #	Dose Rate	Test Levels (krad(Si))
1-5	5	Biased	1-5	LDR 0.01 rad (Si)/s	0, 2, 5, 10, 15, 20
6-10	5	Unbiased	6-10	LDR 0.01 rad(Si)/s	0, 2, 5, 10, 15, 20

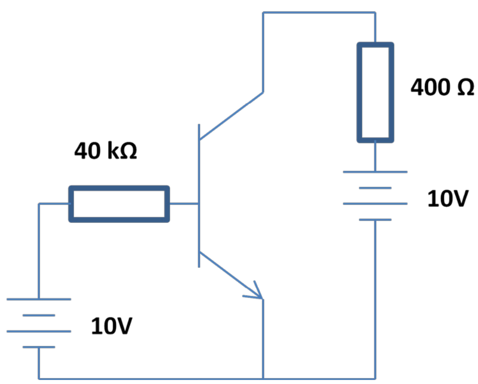

Figure 4. Bias circuit used in testing parts exposed under bias.

4. Results

Results for the collector cut-off current, I_{CBO}, are shown in Table 3. DUTs 1-5 were irradiated under bias, as shown in Fig. 4, and DUTs 6-10 were irradiated with all pins grounded. Measured values for all ten test DUTs, plus the unirradiated control device, are shown at each exposure level , 0-20 Krads (Si), along with results after a one week anneal. At each exposure condition, the mean (μ), standard deviation (σ), minimum, and maximum values are given for the group of five biased samples, and also for the group of five unbiased (Grounded) samples. Also given for both the biased and unbiased groups, is the 99/90 confidence limit. To determine this limit, we assume a large population of nominally identical devices with a normal distribution of I_{CBO} values, where the mean and standard deviation for the entire population are unknown. Using the mean and standard deviation determined for our sample of five parts to estimate the mean and standard deviation for the entire population, we determine the confidence limits given in the Table. The meaning is that we have 90% confidence that 99% of the data for the entire population will fall below the stated confidence limit. Since the calculated confidence limits are all more than four orders of magnitude less than the manufacturer's stated maximum allowed value, 50 nA, all DUTs pass this test easily, at all dose levels. We also note that there is no statistically significant difference between the biased and unbiased groups of parts. We use the Student's t-test,

where the value of t is given in the table. Generally, if t is greater than some critical value, the difference between the groups is taken to be statistically significant. For example, if $t>2.306$, there is a 95% probability that the difference between the groups is not due to chance. Here, one measurement, at 20 Krads (Si) actually does have $t>t_{crit}$. For seven independent measurements, where each one has a 5% chance of exceeding t_{crit}, just by chance, the probability that none of them will do so is $(0.95)^7$, or about 70%. That is, there is about one chance in three that one measurement will appear to give a significant result here, just by chance. In this case, we note that for both the measurement before and the measurement after the 20 Krad (Si) measurement, t falls short of t_{crit} by more than a factor of 10. Clearly, there is no trend toward increasing t, with dose. Therefore, we conclude there is no statistically significant difference between the biased and unbiased results. There is a statistically significant difference between pre-radiation values and post-radiation values, because I_{CBO} generally got smaller, both for biased and unbiased conditions. Since only a maximum specification was given, the impact is that I_{CBO} is within specification, with even more margin after radiation, than before radiation.

	Spec Limit Max	DUT No.	Pre-rad 0 Krads (A)	2 Krad (A)	5 Krad (A)	10 Krads (A)	15 Krad (A)	20 Krad (A)	Anneal (A)
I_{CBO} (A) 10V	50 nA dc	Control	1.46E-12	8.69E-13	4.90E-13	6.74E-13	1.06E-12	5.79E-13	4.67E-13
		1	2.20E-12	1.18E-12	8.10E-13	1.41E-12	1.46E-12	7.91E-13	1.19E-12
		2	1.88E-12	1.23E-12	8.12E-13	1.40E-12	1.32E-12	5.86E-13	1.05E-12
		3	2.10E-12	1.07E-12	7.86E-13	1.09E-12	1.13E-12	5.36E-13	1.05E-12
		4	2.09E-12	1.59E-12	7.31E-13	1.59E-12	1.58E-12	8.37E-13	1.11E-12
		5	3.12E-12	1.19E-12	1.50E-12	1.24E-12	1.43E-12	7.90E-13	8.72E-13
		6	2.14E-12	2.07E-12	7.39E-13	1.89E-12	1.91E-12	1.53E-12	1.73E-12
		7	2.18E-12	1.16E-12	6.30E-13	1.23E-12	1.34E-12	8.98E-13	8.13E-13
		8	1.46E-12	1.32E-12	7.35E-13	1.06E-12	1.14E-12	8.93E-13	9.13E-13
		9	1.81E-12	1.14E-12	7.35E-13	1.09E-12	1.21E-12	9.93E-13	8.64E-13
		10	2.11E-12	1.41E-12	8.20E-13	1.11E-12	1.24E-12	1.06E-12	7.81E-13
	Biased	μ	2.28E-12	1.25E-12	9.28E-13	1.34E-12	1.38E-12	7.08E-13	1.06E-12
		σ	4.83E-13	2E-13	3.21E-13	1.86E-13	1.69E-13	1.37E-13	1.17E-13
		Min	1.88E-12	1.07E-12	7.31E-13	1.09E-12	1.13E-12	5.36E-13	8.72E-13
		Max	3.12E-12	1.59E-12	1.50E-12	1.59E-12	1.58E-12	8.37E-13	1.19E-12
		99/90	4.54E-12	2.18E-12	2.43E-12	2.22E-12	2.17E-12	1.35E-12	1.60E-12
	GND	μ	1.94E-12	1.42E-12	7.32E-13	1.28E-12	1.37E-12	1.08E-12	1.02E-12
		σ	3.08E-13	3.8E-13	6.75E-14	3.51E-13	3.11E-13	2.63E-13	4E-13
		Min	1.46E-12	1.14E-12	6.30E-13	1.06E-12	1.14E-12	8.93E-13	7.81E-13
		Max	2.18E-12	2.07E-12	8.20E-13	1.89E-12	1.91E-12	1.53E-12	1.73E-12
		99/90	3.38E-12	3.20E-12	1.05E-12	2.91E-12	2.83E-12	2.31E-12	2.89E-12
		t	1.317	0.89	1.332	0.39	0.085	2.767	0.19

Table 3. I_{CBO} results, where maximum spec limit is 50 nAdc. Dose is in Krads (Si), Anneal time is 168 hours at 25°C.

Results for gain (h_{fe}) testing are presented in Table 4. The manufacturer's specification is that the gain should be in the range 65-135, and all DUTs at all dose levels fall in this range. The minimum for any DUT is a gain of 91.6, while the maximum is 112. The mean, standard deviation, minimum value, maximum value, and 99/90 high and low confidence limits are determined separately for the biased and unbiased samples. The procedure for determining confidence limits is slightly different in Table 4, than it was in Table 3. In Table 3, ony a maximum specification was given, so a one-sided confidence limit was determined. In Table 4,

both an upper limit and a lower limit are given, so a two-sided calculation has been performed. The 99/90 confidence limits are calculated, assuming that the gain is normally distributed. Under this assumption, we calculate there is a 90% probability that 99% of the device population from which the test samples are drawn, will fall between the calculated upper and lower limits. In all cases, these limits are within the specification. Calculated t-values less than $t_{crit}=2.306$ indicate that there is no statistically significant difference between the biased and unbiased radiation conditions. In all cases, $t<t_{crit}$. There is also no statistically significant difference between pre-radiation values and those at the end of the test, for either biased or unbiased samples.

	Min Spec Limit	Max Spec Limit	DUT No.	Pre-rad	2 Krads	5 Krads	10 Krads	15 Krads	20 Krads	Anneal
h_{fe}	65	135	Control	100.98	94.23	99.56	101.27	102.55	102.09	102.33
			1	109.04	101.65	109.43	109.86	109.69	110.26	110.05
			2	109.51	101.97	110.11	110.04	110.25	110.20	110.59
			3	105.90	98.70	107.05	106.06	106.06	107.58	107.88
			4	100.06	93.47	100.19	100.28	100.36	102.06	102.24
			5	104.13	96.78	106.31	104.48	104.25	105.53	106.19
			6	103.37	97.28	104.33	104.69	105.07	105.59	105.89
			7	105.15	97.77	105.52	105.61	105.58	107.03	106.76
			8	98.22	91.57	98.67	98.64	98.67	100.28	100.46
			9	111.90	102.82	107.65	107.59	107.79	108.77	108.99
			10	99.34	93.27	99.80	99.50	99.81	101.53	97.06
		Biased	µ	1.06E+02	9.85E+01	1.07E+02	106	106	107	107
			σ	3.87	3.54	3.930	4.06	4.076	3.451	3.373
			Min	1.00E+02	9.35E+01	1.00E+02	100	100	102	102
			Max	1.10E+02	1.02E+02	1.10E+02	110	110	110	111
		99/90	High	1.27E+02	1.18E+02	1.28E+02	128	128	126	126
		99/90	Low	8.48E+01	7.93E+01	8.53E+01	84.1	84.1	88.4	89.1
		GND	µ	1.04E+02	9.65E+01	1.03E+02	103	103	105	104
			σ	5.440	4.383	3.825	3.926	3.942	3.615	4.914
			Min	9.82E+01	9.16E+01	9.87E+01	98.6	98.7	100	97.1
			Max	1.12E+02	1.03E+02	1.08E+02	108	108	109	109
		99/90	High	1.33E+02	1.20E+02	1.24E+02	124	125	124	130
		99/90	Low	7.41E+01	7.28E+01	8.25E+01	81.9	82.0	85.0	77.2
			t	0.714	0.783	1.049	1.162	1.08	1.112	1.335

Table 4. Gain (h_{fe}) results. Spec range is 65-135 in all cases. Dose is in Krads (Si). Anneal time is 168 hours at 25°C. DUTs 1-5 were exposed with bias; DUT6-10 were exposed with all pins grounded.

	Typ Spec Limit	DUT No.	Total	Pre-rad Real Value	Total	2 Krads Real Value	Total	5 Krads real value
Collector Capacitance	**0.6 pF**	**None**	4.79E-13		4.79E-13		7.27E-13	
		Control	1.05E-12	**5.68E-13**	1.01E-12	**5.35E-13**	1.31E-12	**5.81E-13**
		1	1.04E-12	**5.64E-13**	9.93E-13	**5.14E-13**	1.28E-12	**5.52E-13**
		2	1.05E-12	**5.67E-13**	1.01E-12	**5.28E-13**	1.26E-12	**5.34E-13**
		3	1.02E-12	**5.40E-13**	1.00E-12	**5.24E-13**	1.24E-12	**5.16E-13**
		4	1.04E-12	**5.56E-13**	1.05E-12	**5.69E-13**	1.27E-12	**5.46E-13**
		5	1.10E-12	**6.17E-13**	1.03E-12	**5.55E-13**	1.31E-12	**5.79E-13**
		6	1.01E-12	**5.33E-13**	9.92E-13	**5.13E-13**	1.25E-12	**5.24E-13**
		7	1.01E-12	**5.34E-13**	9.95E-13	**5.16E-13**	1.26E-12	**5.34E-13**
		8	1.01E-12	**5.32E-13**	1.01E-12	**5.27E-13**	1.26E-12	**5.32E-13**
		9	1.04E-12	**5.57E-13**	1.04E-12	**5.60E-13**	1.30E-12	**5.71E-13**
		10	1.04E-12	**5.57E-13**	1.06E-12	**5.85E-13**	1.25E-12	**5.25E-13**
	Biased	**Mean**		5.69E-13		5.38E-13		5.45E-13
		Std Dev		2.89E-14		2.3E-14		2.33E-14
		Min		5.40E-13		5.14E-13		5.16E-13
		Max		6.17E-13		5.69E-13		5.79E-13
		99/90-H		7.25E-13		6.63E-13		6.72E-13
		99/90-L		4.12E-13		4.13E-13		4.19E-13
	Unbiased	**Mean**		5.43E-13		5.40E-13		5.37E-13
		Std Dev		1.32E-14		3.12E-14		1.94E-14
		Min		5.32E-13		5.13E-13		5.24E-13
		Max		5.57E-13		5.85E-13		5.71E-13
		99/90H		6.14E-13		7.09E-13		6.42E-13
		99/90 L		4.71E-13		3.71E-13		4.32E-13
		t		1.844		0.127		0.605

A.

DUT No.	Total	10 Krads True Value	Total	15 Krads True Value	Total	20 Krads True Value	Total	Anneal True Value
None	7.19E-13		4.93E-13		4.69E-13		5.24E-13	
Control	1.26E-12	**5.45E-13**	1.06E-12	**5.65E-13**	1.02E-12	**5.53E-13**	1.07E-12	**5.45E-13**
1	1.28E-12	**5.65E-13**	1.04E-12	**5.51E-13**	1.02E-12	**5.50E-13**	1.05E-12	**5.23E-13**
2	1.28E-12	**5.64E-13**	1.05E-12	**5.53E-13**	1.03E-12	**5.58E-13**	1.07E-12	**5.41E-13**
3	1.26E-12	**5.39E-13**	1.02E-12	**5.25E-13**	1.02E-12	**5.53E-13**	1.04E-12	**5.16E-13**
4	1.24E-12	**5.24E-13**	1.04E-12	**5.45E-13**	1.03E-12	**5.56E-13**	1.06E-12	**5.34E-13**
5	1.28E-12	**5.63E-13**	1.09E-12	**5.93E-13**	1.07E-12	**6.03E-13**	1.11E-12	**5.84E-13**
6	1.26E-12	**5.40E-13**	1.04E-12	**5.48E-13**	1.01E-12	**5.40E-13**	1.03E-12	**5.09E-13**
7	1.24E-12	**5.17E-13**	1.03E-12	**5.32E-13**	1.01E-12	**5.42E-13**	1.05E-12	**5.23E-13**
8	1.25E-12	**5.29E-13**	1.03E-12	**5.34E-13**	1.01E-12	**5.42E-13**	1.04E-12	**5.17E-13**
9	1.29E-12	**5.73E-13**	1.06E-12	**5.63E-13**	1.04E-12	**5.72E-13**	1.08E-12	**5.52E-13**
10	1.24E-12	**5.22E-13**	1.03E-12	**5.37E-13**	1.00E-12	**5.35E-13**	1.04E-12	**5.14E-13**
Biased µ		5.51E-13		5.53E-13		5.64E-13		5.40E-13
Std Dev		1.86E-14		2.48E-14		2.2E-14		2.66E-14
Min		5.24E-13		5.25E-13		5.50E-13		5.16E-13
Max		5.65E-13		5.93E-13		6.03E-13		5.84E-13
99/90H		6.52E-13		6.88E-13		6.83E-13		6.84E-13
99/90L		4.50E-13		4.19E-13		4.45E-13		3.95E-13
Unbiased µ		5.36E-13		5.43E-13		5.46E-13		5.23E-13
Std Dev		2.23E-14		1.29E-14		1.47E-14		1.7E-14
Min		5.17E-13		5.32E-13		5.35E-13		5.09E-13
Max		5.73E-13		5.63E-13		5.72E-13		5.52E-13
99/90H		6.57E-13		6.13E-13		6.26E-13		6.15E-13
99/90L		4.15E-13		4.73E-13		4.67E-13		4.31E-13
t		1.14		0.849		1.504		1.175

B.

Table 5. Collector capacitance results. Capacitance value indicated where DUT is indicated as "None" is the capacitance associated with the test fixture with no DUT attached. Columns marked "Total" indicate the capacitance with a DUT in the test fixture. Columns indicated as "True Value" are the DUT capacitance alone, after the capacitance of the test fixture is subtracted out. All DUTs at all dose levels are close to the typical spec, 0.6 pF. The full range of data is 0.517 pF to 0.617 pF. No upper or lower specification limits are given, but the standard deviation is less than 5% of the mean in nearly all cases. Mean, standard deviation, minimum and maximum values, and high and low 99/90 confidence limits are determined separately for

biased and unbiased groups of samples. The parameter t is less than t_{crit} in all cases, indicating no statistically significant difference between biased and unbiased irradiation. There is also not statistically significant difference between pre-radiation values and post-radiation values, for either biased or unbiased test conditions.

Emitter Capacitance	Typ Spec Limit	DUT No.	Total (F)	Pre-Rad Real Value	Total (F)	2 Krad Real Value	Total (F)	5 Krad Real Value
	1.2 pF	None	5.51E-13		5.31E-13		7.65E-13	
		Control	1.30E-12	**7.48E-13**	1.35E-12	**8.16E-13**	1.58E-12	**8.11E-13**
		1	1.35E-12	**7.94E-13**	1.32E-12	**7.90E-13**	1.57E-12	**8.03E-13**
		2	1.35E-12	**7.94E-13**	1.32E-12	**7.90E-13**	1.59E-12	**8.21E-13**
		3	1.36E-12	**8.08E-13**	1.35E-12	**8.15E-13**	1.56E-12	**7.92E-13**
		4	1.38E-12	**8.25E-13**	1.38E-12	**8.45E-13**	1.60E-12	**8.37E-13**
		5	1.40E-12	**8.44E-13**	1.38E-12	**8.51E-13**	1.59E-12	**8.27E-13**
		6	1.26E-12	**7.10E-13**	1.35E-12	**8.22E-13**	1.56E-12	**7.99E-13**
		7	1.33E-12	**7.74E-13**	1.33E-12	**8.01E-13**	1.54E-12	**7.72E-13**
		8	1.36E-12	**8.05E-13**	1.34E-12	**8.08E-13**	1.57E-12	**8.02E-13**
		9	1.39E-12	**8.43E-13**	1.36E-12	**8.30E-13**	1.55E-12	**7.80E-13**
		10	1.36E-12	**8.08E-13**	1.36E-12	**8.31E-13**	1.57E-12	**8.04E-13**
	Biased	Mean		8.05E-13		8.10E-13		8.13E-13
		Std Dev		1.47E-14		2.61E-14		1.98E-14
		Min		7.94E-13		7.90E-13		7.92E-13
		Max		8.25E-13		8.45E-13		8.37E-13
	High	99/90		8.85E-13		9.52E-13		9.21E-13
	Low	99/90		7.25E-13		6.68E-13		7.06E-13
	Unbiased	Mean		7.88E-13		8.18E-13		7.91E-13
		Std Dev		5E-14		1.34E-14		1.44E-14
		Min		7.10E-13		8.01E-13		7.72E-13
		Max		8.43E-13		8.31E-13		8.04E-13
	High	99/90		1.06E-12		8.91E-13		8.70E-13
	Low	99/90		5.17E-13		7.46E-13		7.13E-13
		t		1.027		0.014		2.363

A.

DUT No.	Total (F)	10 Krad True Value	Total (F)	15 Krad True Value	Total (F)	20 Krad True Value	Total (F)	Anneal True Value
None	7.77E-13		5.49E-13		5.26E-13		5.61E-13	
Control	1.62E-12	**8.41E-13**	1.37E-12	**8.16E-13**	1.36E-12	**8.34E-13**	1.38E-12	**8.23E-13**
1	1.52E-12	**7.45E-13**	1.33E-12	**7.81E-13**	1.35E-12	**8.27E-13**	1.39E-12	**8.24E-13**
2	1.59E-12	**8.12E-13**	1.35E-12	**7.99E-13**	1.35E-12	**8.24E-13**	1.37E-12	**8.04E-13**
3	1.58E-12	**8.06E-13**	1.34E-12	**7.88E-13**	1.35E-12	**8.22E-13**	1.39E-12	**8.24E-13**
4	1.61E-12	**8.32E-13**	1.38E-12	**8.30E-13**	1.39E-12	**8.67E-13**	1.41E-12	**8.47E-13**
5	1.64E-12	**8.67E-13**	1.40E-12	**8.48E-13**	1.40E-12	**8.72E-13**	1.44E-12	**8.74E-13**
6	1.61E-12	**8.31E-13**	1.35E-12	**8.04E-13**	1.35E-12	**8.27E-13**	1.39E-12	**8.29E-13**
7	1.59E-12	**8.13E-13**	1.26E-12	**7.11E-13**	1.32E-12	**7.92E-13**	1.37E-12	**8.06E-13**
8	1.59E-12	**8.11E-13**	1.36E-12	**8.12E-13**	1.36E-12	**8.35E-13**	1.37E-12	**8.09E-13**
9	1.59E-12	**8.14E-13**	1.36E-12	**8.06E-13**	1.36E-12	**8.37E-13**	1.38E-12	**8.20E-13**
10	1.57E-12	**7.91E-13**	1.36E-12	**8.13E-13**	1.36E-12	**8.30E-13**	1.40E-12	**8.36E-13**
Biased µ		7.99E-13		8.00E-13		8.35E-13		8.25E-13
Std Dev		3.75E-14		2.16E-14		2.14E-14		1.76E-14
Min		7.45E-13		7.81E-13		8.22E-13		8.04E-13
Max		8.32E-13		8.30E-13		8.67E-13		8.47E-13
99/90H		1.00E-12		9.17E-13		9.51E-13		9.20E-13
99/90L		5.95E-13		6.82E-13		7.19E-13		7.29E-13
Unbiased µ		8.12E-13		7.89E-13		8.24E-13		8.20E-13
Std Dev		1.42E-14		4.39E-14		1.84E-14		1.28E-14
Min		7.91E-13		7.11E-13		7.92E-13		8.06E-13
Max		8.31E-13		8.13E-13		8.37E-13		8.36E-13
99/90H		8.89E-13		1.03E-12		9.24E-13		8.89E-13
99/990L		7.35E-13		5.51E-13		7.24E-13		7.51E-13
t		0.191		0.853		1.315		1.100

B.

Table 6. Emitter capacitance results. Capacitance value indicated where DUT is indicated as "None" is the capacitance associated with the test fixture with no DUT attached. Columns marked "Total" indicate the capacitance with a DUT in the test fixture. Columns indicated as "True Value" are the DUT capacitance alone, after the capacitance of the test fixture is subtracted out. All DUTs measure about 0.8 pF compared to a typical spec of 1.2 pF, before irradiation. No upper or lower limits are given. All DUTs remain at about 0.8 pF, at all dose levels. Mean, standard deviation, minimum, maximum, and 99/90 high and low confidence limits are determined separately for biased and unbiased groups of samples. The parameter, t, is determined in the Student's t-test, where t<2.306 indicates a 95% probability the difference

between the biased and unbiased samples is not statistically significant. There is also no statistically significant difference in results before and after radiation, for either biased or unbiased samples.

Feedback Capacitance	Typ Spec Limit	DUT No.	Total (F)	Pre-Rad Real Value	Total (F)	2 Krad Real Value	Total (F)	5 Krad Real Value
	0.35 pF	**None**	3.46E-13		3.30E-13		6.19E-13	
		Control	6.99E-13	**3.53E-13**	6.91E-13	**3.61E-13**	9.79E-13	**3.60E-13**
		1	7.62E-13	**4.16E-13**	6.87E-13	**3.57E-13**	9.79E-13	**3.60E-13**
		2	7.64E-13	**4.18E-13**	6.99E-13	**3.69E-13**	9.33E-13	**3.14E-13**
		3	7.41E-13	**3.95E-13**	6.78E-13	**3.48E-13**	9.46E-13	**3.27E-13**
		4	7.78E-13	**4.32E-13**	6.91E-13	**3.61E-13**	9.60E-13	**3.41E-13**
		5	7.85E-13	**4.39E-13**	7.22E-13	**3.92E-13**	1.02E-12	**4.00E-13**
		6	6.84E-13	**3.38E-13**	6.83E-13	**3.53E-13**	9.54E-13	**3.35E-13**
		7	6.83E-13	**3.37E-13**	6.75E-13	**3.45E-13**	9.45E-13	**3.26E-13**
		8	6.82E-13	**3.36E-13**	8.21E-13	**4.91E-13**	9.10E-13	**2.91E-13**
		9	7.11E-13	**3.65E-13**	8.51E-13	**5.21E-13**	9.89E-13	**3.70E-13**
		10	7.00E-13	**3.54E-13**	6.90E-13	**3.60E-13**	9.60E-13	**3.41E-13**
	Biased	**Mean**		4.15E-13		3.59E-13		3.36E-13
		Std Dev		1.53E-14		8.73E-15		1.97E-14
		Min		3.95E-13		3.48E-13		3.14E-13
		Max		4.32E-13		3.69E-13		3.60E-13
	High	**99/90**		4.98E-13		4.06E-13		4.42E-13
	Low			3.33E-13		3.11E-13		2.29E-13
	Unbiased	**Mean**		3.46E-13		4.14E-13		3.33E-13
		Std Dev		1.29E-14		8.48E-14		2.85E-14
		Min		3.36E-13		3.45E-13		2.91E-13
		Max		3.65E-13		5.21E-13		3.70E-13
	High	**99/90**		4.16E-13		8.74E-13		4.87E-13
	Low	**99/90**		2.76E-13		-4.6E-14		1.78E-13
		t		7.757		1.257		0.803

A.

DUT No.	Total (F)	10 Krad Real Value	Total (F)	15 krad Real Value	Total (F)	20 Krad Real Value	Total (F)	Anneal Real Value
None	6.01E-13		3.54E-13		3.620E-13		4.220E-13	
Control	9.77E-13	**3.76E-13**	6.99E-13	**3.45E-13**	7.060E-13	**3.44E-13**	7.620E-13	**3.40E-13**
1	9.67E-13	**3.66E-13**	7.17E-13	**3.63E-13**	7.280E-13	**3.66E-13**	7.750E-13	**3.53E-13**
2	9.84E-13	**3.83E-13**	7.20E-13	**3.66E-13**	7.080E-13	**3.46E-13**	7.710E-13	**3.49E-13**
3	9.43E-13	**3.42E-13**	6.91E-13	**3.37E-13**	6.910E-13	**3.29E-13**	7.480E-13	**3.26E-13**
4	9.56E-13	**3.55E-13**	6.84E-13	**3.30E-13**	8.190E-13	**4.57E-13**	8.370E-13	**4.15E-13**
5	1.01E-12	**4.12E-13**	7.17E-13	**3.63E-13**	7.590E-13	**3.97E-13**	8.010E-13	**3.79E-13**
6	9.51E-13	**3.50E-13**	6.92E-13	**3.38E-13**	6.840E-13	**3.22E-13**	7.490E-13	**3.27E-13**
7	9.45E-13	**3.44E-13**	7.02E-13	**3.48E-13**	6.740E-13	**3.12E-13**	7.550E-13	**3.33E-13**
8	9.42E-13	**3.41E-13**	6.86E-13	**3.32E-13**	6.960E-13	**3.34E-13**	7.680E-13	**3.46E-13**
9	9.87E-13	**3.86E-13**	7.06E-13	**3.52E-13**	7.480E-13	**3.86E-13**	8.000E-13	**3.78E-13**
10	9.60E-13	**3.59E-13**	6.99E-13	**3.45E-13**	6.830E-13	**3.21E-13**	7.750E-13	**3.53E-13**
Bias/μ		3.62E-13		3.49E-13		3.75E-13		3.61E-13
Std Dev		1.74E-14		1.82E-14		5.7E-14		3.81E-14
Min		3.42E-13		3.30E-13		3.29E-13		3.26E-13
Max		3.83E-13		3.66E-13		4.57E-13		4.15E-13
99/90H		4.56E-13		4.47E-13		6.84E-13		5.67E-13
99/90L		2.67E-13		2.51E-13		6.53E-14		1.54E-13
Unbias/μ		3.56E-13		3.43E-13		3.35E-13		3.47E-13
Std Dev		1.81E-14		8E-15		2.96E-14		2E-14
Min		3.41E-13		3.32E-13		3.12E-13		3.27E-13
Max		3.86E-13		3.52E-13		3.86E-13		3.78E-13
99/90H		4.54E-13		3.86E-13		4.95E-13		4.56E-13
99/90L		2.58E-13		3.00E-13		1.75E-13		2.39E-13
t		1.069		1.051		1.683		0.965

B.

Table 7. Feedback capacitance results. Capacitance value indicated where DUT is indicated as “None” is the capacitance associated with the test fixture with no DUT attached. Columns marked “Total” indicate the capacitance with a DUT in the test fixture. Columns indicated as “True Value” are the DUT capacitance alone, after the capacitance of the test fixture is subtracted out. Typical spec is 0.35 pF, and actual values pre-radiation range from 0.34 pF to 0.42 pF. Values change very little with dose. Mean, standard deviation, minimum, maximum and 99/90 high and low confidence limits are all determined separately for biased and unbiased groups of samples. Parameter t indicates whether or not there is a statistically significant difference between biased and unbiased sample groups. Strangely, in this Table, the calculated value of t indicates a significant difference, but only for the pre-radiation measurements. For

unbiased samples, there was no statistically significant difference before and after radiation. For the biased samples, the difference before and after radiation is statistically significant. Even so, all DUTs are close to the nominal value at all dose levels.

Switching Time at 2 GHz	Spec	DUT No.	Pre-Radiation	2 Krad	5 Krad	10 Krad	15 Krad	20 Krad	Anneal
		Control	Good	Good	Good	Good	Good	Good	Good
		1	Good	Good	Good	Good	Good	Good	Good
		2	Good	Good	Good	Good	Good	Good	Good
		3	Good	Good	Good	Good	Good	Good	Good
		4	Good	Good	Good	Good	Good	Good	Good
		5	Good	Good	Good	Good	Good	Good	Good
		6	Good	Good	Good	Good	Good	Good	Good
		7	Good	Good	Good	Good	Good	Good	Good
		8	Good	Good	Good	Good	Good	Good	Good
		9	Good	Good	Good	Good	Good	Good	Good
		10	Good	Good	Good	Good	Good	Good	Good

Table 8. Summary of switching waveforms at 2 GHZ. Typical oscilloscope trace is shown in Fig. 5.

The most important property of these high speed transistors is the ability to switch at high frequency. Although the test equipment was not adequate to exercise the test transistors at the 5 Ghz specification, the guidance from the program was that demonstrating the ability to switch at 1 ns or faster was critical. A typical oscilloscope trace, showing switching in 0.5 ns, is shown in Fig. 5. All DUTs at all dose levels had the same response as that shown in Fig. 5, which is adequate for program requirements.

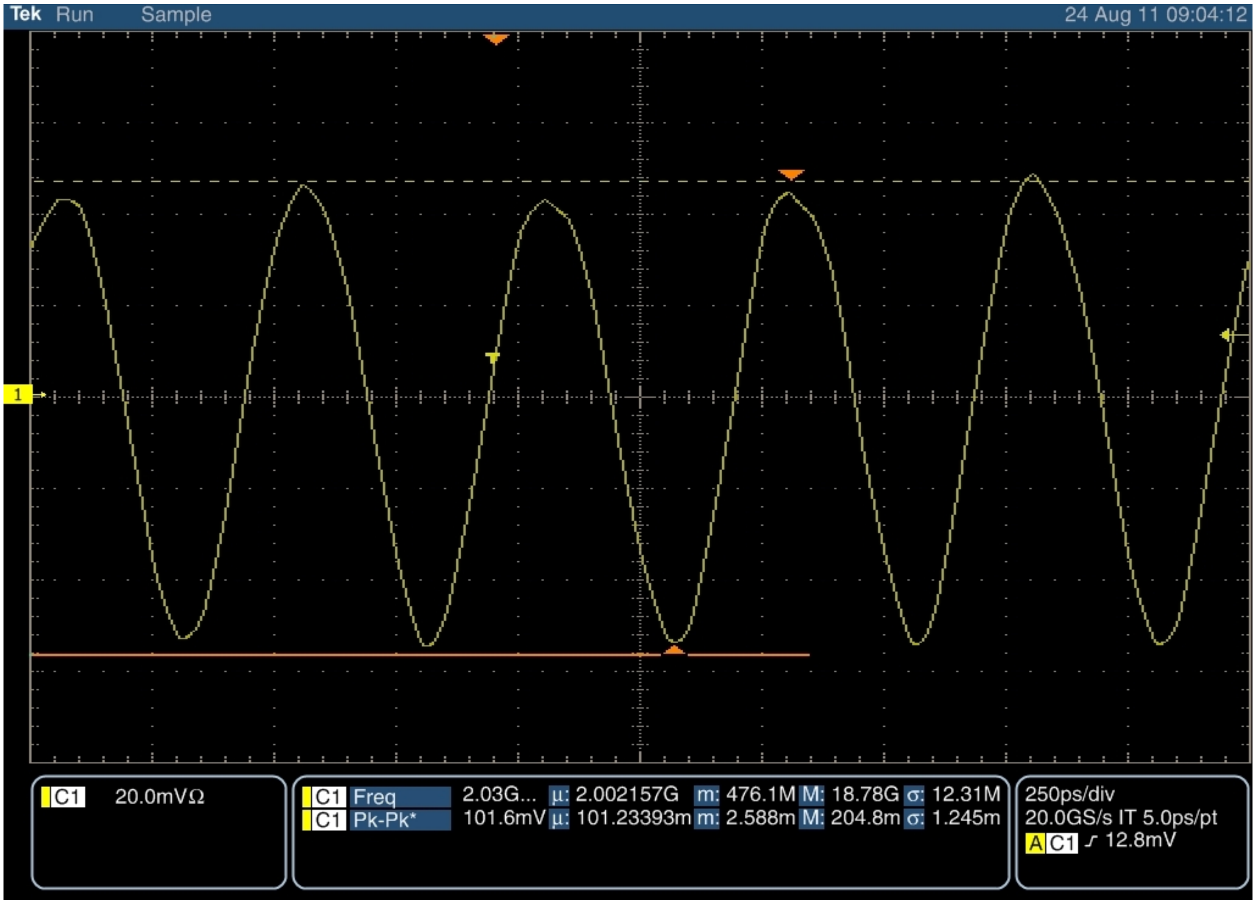

Fig. 5. Oscilloscope trace, showing a BFR92A switching at a frequency of 2GHz, after 20 Krads (Si) and an anneal period. Traces for all DUTs at all dose levels look similar, at this frequency. At higher frequencies, the waveforms start to show distortion, because of limitations of the test equipment.

5. Conclusions

The BFR92A has a good radiation response up to the total dose used in this test. All measured parameters, for every DUT, are within the manufacturer's specification at every dose level. The switching speed, which could not be measure up to the full 5 GHz specification because of limitations of the test equipment available, was measured and exceeds the stated requirements of the mission by a comfortable margin. There was no statistically significant difference between parts irradiated with bias and those irradiated without bias, for any parameter, at any point in the test.